THE DISTRIBUTION OF MOSQUITO (DIPTERA, CULICIDAE) LARVAE IN SOUTHERN ALBERTA, 1976-1978

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ABSTRACT

Twenty-seven species of Aedes, *four species of* Culiseta , *two species of* Culex *and one species of* Anopheles *were collected during five surveys of water bodies in Alberta south of 52°N during 1976, 1977 and 1978. Identifications were made on 4th stage larvae and confirmed after rearing to adult. The species of* Aedes *showed four distribution patterns: Group 1 was largely restricted to the mountains and foothills; Group 2 was found in all parts of the study area; Group 3 occurred everywhere but in the prairie zone; Group 4 was largely restricted to the parkland and prairie. Because of low numbers, the distribution of seven species of* Aedes *could not be determined. Of the species in other genera, only* Culiseta inornata *(a Group 2 species) was common enough to determine distribution, although* Cs. alaskaensis *appears to belong to Group 1. Apart from these broad patterns, the habitat preferences of individual species could not be determined. Of the 20 commonest species, 18 were associated with 13-20 other species at one time or another, and two had nine associated species. The number of pools that formed by snow-melt or rain-fall, the dates of appearance of larvae, and the relative species abundance all changed markedly from year to year.*

RÉSUMÉ

Vingt-sept espèces d' Aedes, *quatre espèces de* Culiseta, *deux espèces de* Culex *et une espèce d'* Anopheles *ont été collectionnées au cours de cinq inventaires des plans d'eau situés au sud du 52ième parallèle Nord en Alberta, en 1976, 1977 et 1978. Les espèces ont été identifiées à partir des larves du quatrième stade, et les identifications ont été vérifiées*

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*grâce à l'elevage de ces mêmes larvaes jusqu'au stade adulte. La distribution des espèces d'*Aedes *formait quatre patrons: le groupe 1 était principalement restreint aux montagnes et aux piedmonts; le groupe 2 se retrouvait dans toutes les régions inventoriées; le groupe 3 se retrouvait partout, sauf dans la prairie; le groupe 4 était en grande partie restreint au "parkland" et à la prairie. La distribution de sept espèces d'*Aedes *n pu être établie à cause des faibles captures. Parmi les espèces appartenant aux genres autres qu'*Aedes, *seule* Culiseta inornata *était assez commune pour pouvoir établir sa répartition (elle se classe dans le groupe 2);* Cs. alaskaensis *semble appartenir au groupe 1. Mis à part ces patrons de distribution généraux, l'habitat préféré de chaque espèce n'a pu être déterminé. Parmi les vingt espèces les plus communes, dix-huit étaient associées avec de treize à vingt autres espèces à une occasion ou l'autre, et deux espèces se retrouvaient chacune en association avec neuf espèces. Le nombre d'étangs formés par la fonte des neige ou la pluie, les dates d'émergence des larvaes, et l'abondance relative des espèces ont tous variés d'une année à l'autre.*

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INTRODUCTION

Proper identification of species is basic to any biological study. Furthermore, studies of mosquito-carried diseases and mosquito abatement in Alberta cannot make efficient use of data already accumulated and analysed unless the species, both in the current programs and in work already done, are properly known. The problem of adult migration into an area in which a larviciding program has been carried out, can hardly begin to be solved without thorough knowledge of the species involved.

In the report of the "Symposium on Biting Fly Control and Environmental Quality" held in Edmonton in 1972, the summary of the section on *Behaviour and Ecology of Populations* (McIver, 1973) contained the following passage:

> " When considering a control program, four superficially simple questions need to be asked about the pest species: 1. What is it? 2. Where is it? 2. What is it doing? 4. How does it accomplish its observed behaviour?"

This report attempts to answer the first two questions for mosquitoes in Southern Alberta. Such a study was necessary because, although several reports about mosquitoes of Alberta have included species lists (e.g. Strickland, 1938; Happold, 1965; Pucat, 1965; Wada, 1965; Tawfik and Gooding, 1970), these studies represented a limited approach to species identification and all contained some misidentifications through use of incomplete or inaccurate keys. For example, Enfield (1977) reported that two species, *Aedes euedes* Howard, Dyar and Knab 1917 and *Aedes mercurator* Dyar 1920 have long remained unrecognized. Larvae of *Aedes euedes* key to *Aedes riparius* Dyar and Knab in Rempel (1950) and Carpenter and LaCasse (1955), while adult males have genitalia that resemble those of *Aedes excrucians* (Walker) . *Aedes barri* Rueger 1958 and *Aedes beklemishevi* Denisova 1955 are synonyms for *Aedes euedes* (Wood, 1977). *Aedes mercurator* larvae key to one of four other species in conventional keys. Until this species was recognized in Calgary in 1975 (Enfield, 1977), it was recorded only from Dawson, Yukon Territory (Dyar, 1920), and from the U.S.S.R. (Danilov, 1974). Many adults labelled *Aedes stimulans* (Walker) in the Canadian National Insect Collection are in fact *Aedes mercurator* , and its range is now known to extend across much of Northern Canada (Wood, 1977).

These problems stimulated a survey of the mosquitoes in Southern Alberta. We felt that the area of Alberta approximately south of latitude 52°N, within which Calgary is conveniently central, was the maximum that could be covered in a study of this kind. Further, we thought that only by collecting extensively in all ecological zones and by both identifying larvae and rearing them to obtain associated adults, could familiarity with the whole group be gained and problems such as those involving *Aedes mercurator* and *Aedes euedes* be exposed.

The data, which are summarized in this paper, may be found in a more extensive form, together with a key to 4th stage *Aedes* larvae occurring in southern Alberta in an unpublished report (Scholefield, Enfield and Pritchard, 1979).

METHODS

The study area was surveyed five times. Samples of larvae were collected along planned routes so that the major ecological zones and different types of water bodies were included in each trip. Distribution of sites that yielded larvae is shown in Figures 1 & 2. In the Spring (April-May) of 1976, mosquito larvae were collected from 115 sites, from 45 sites in the Spring of 1977, from 61 sites in the Summer (June-July) of 1977, from 124 sites in the Spring of 1978, and from 41 sites in the Summer of 1978.

Most collections were obtained by driving along set routes and sampling water bodies which were seen from the road. However, spring sampling in the Southeast of the province in 1977 and 1978 was done during a helicopter tour by Mr. J. McIntosh (Alberta Environment) to the various abatement areas under his jurisdiction; one slough in or near each town was selected from the air, then sampled. In 1977 and 1978, a record sheet containing information on each site was filled out and a photograph of the site was attached.

Larvae were captured by means of a standard pint dipper, and, wherever possible, dipping was continued at each site until about 50 larvae had been caught. The larvae were concentrated

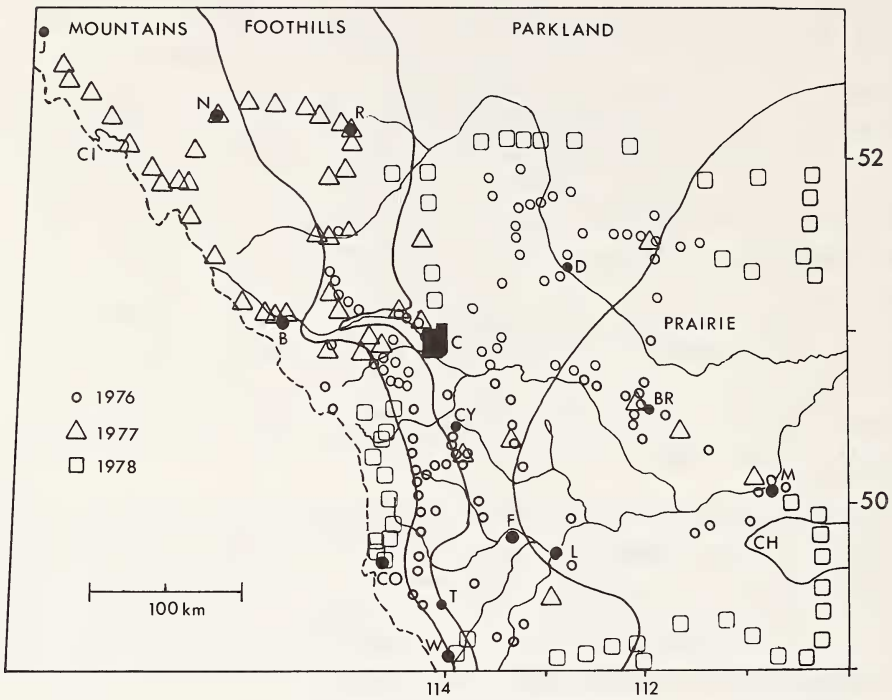

Fig. 1. Sites which yielded mosquito larvae during spring (April-May) sampling. The 1976 survey did not adequately cover the mountain zone and northern foothills and this was corrected in later years. In 1978 the whole region was surveyed but only those areas not visited in previous years are indicated. Also shown are the 4 ecological zones (heavy lines), the Columbia Ice-fields (CI) and the Cypress Hills (CH), the major rivers (thin lines), and some towns (B = Banff, BR = Brooks, C = Calgary, CY = Cayley, CO = Coleman, D = Drumheller, F = Fort McLeod, J = Jasper, L = Lethbridge, M = Medicine Hat, N = Nordegg, R = Rocky Mountain House

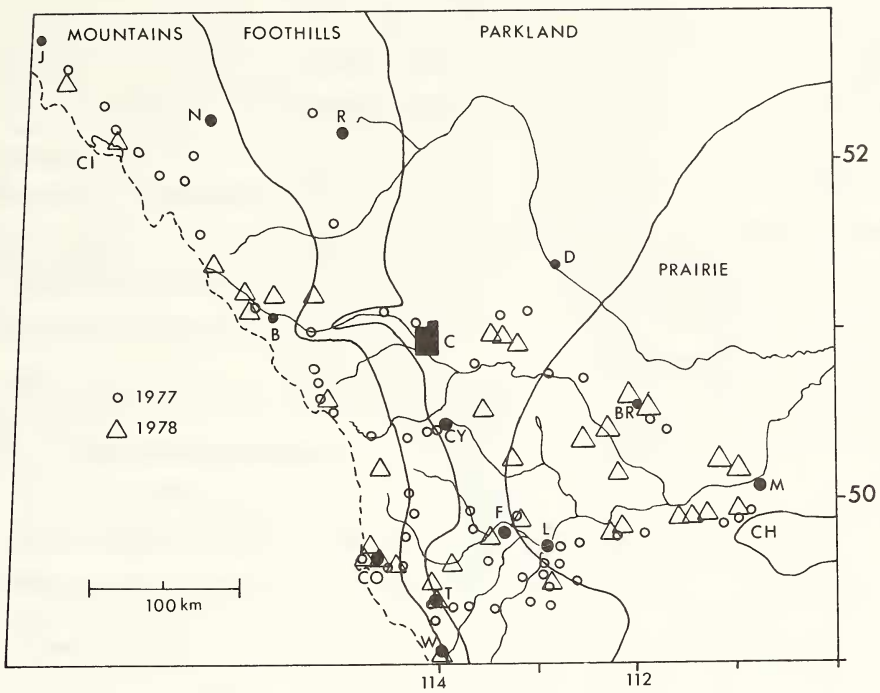

Fig. 2. Sites which yielded mosquito larvae during summer (June-July sampling

in a clear plastic cup by means of a cylindrical filter which was fitted into the top of the cup. As water containing larvae was poured in, the larvae were retained in the cup while excess water spilled out. Usually no more than about 25 larvae were kept in each cup, which was sealed with a plastic lid, and returned to the laboratory in a cooler. When samples were being transported, a stop of five minutes duration was made every 30 minutes to allow larvae to rise to the water surface and breathe. When 4th stage larvae were collected about one-third of the sample was killed in KA&AD [1] and preserved in 95% ethanol. These subsamples were potential replacements in case a whole sample should die during transportation, since mosquito larvae decay very rapidly after death, making identification impossible. Some pupae collected in the field represented species of which there were no larvae in the same sample. Thus collection of pupae for subsequent rearing to the adult stage was important, even though pupae are more difficult to keep alive during transportation.

In the laboratory, larvae were kept in these same plastic cups at 20°C, in tap water which had been conditioned with dead slough grass for one week. The water was aerated to prevent formation of surface scum, and larvae fed on the micro-organisms on the surface of the decaying grass. Larvae were identified when in stage IV and some were returned to the cups to complete development; the remainder were killed in KA&AD and preserved in 95% ethanol.

Because examination of preserved specimens in Edmonton and Calgary showed that many *Aedes* adults and larvae had earlier been misidentified, as many identified larvae as possible were reared to adults and then reidentified to reduce the chance of further misidentification. Pupae were placed individually or in groups of about 20 in cups, and the emerging adults were trapped in inverted plastic vials on top of a funnel made of plastic fly screen. Several hours after emergence, vials containing adults were placed in a freezer to kill the mosquitoes and within a few days the specimens were mounted on a pin with shellac and returned to the freezer for a few weeks to complete drying.

A draft of a key now published in Wood *et al.*, (1979) was the main basis for identification of larvae. Keys of Gjullin and Eddy (1972) and Carpenter and LaCasse (1955) (modified to include *Aedes euedes* and *Ae. mercurator*) were used for identification of adults and for identification of some larvae. Voucher specimens of stage IV larvae and adults of all species are stored in the Department of Biology, University of Calgary.

[1] KAAD = 1 part kerosene, 10 parts 95% ethanol, 2 parts glacial acetic acid and 1 part dioxane. KA&AD = equal parts KAAD and 95% ethanol.

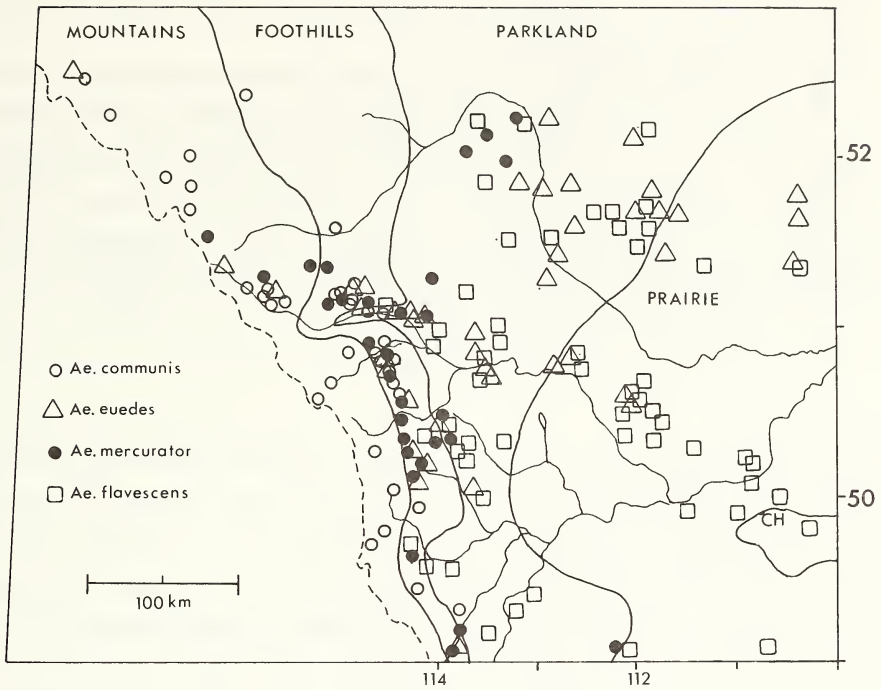

Fig. 3. Examples of the 4 types of distributions Group 1 - Mountains and Foothills: *Ae. communis* : Group 2 - Ubiquitous *Ae. euedes* : Group 3 - Non-Prairie: *Ae. mercurator* ; Group 4 - Prairie and Parkland: *Ae. flavescens.*

The Atlas of Alberta (Government of Alberta, 1969) was used to define ecological zones in preference to the one used by Strickland (1938), because there appeared to be little evidence that the prairie/parkland zone was divisible into as many different areas for *Aedes* species as Strickland showed. Four ecological zones (Mountains, Foothills, Parkland, Prairie) were included within the study area (Figs. 1, 2 & 3).

In 1977 and 1978, in addition to recording location, we attempted to categorize habitat type for each species. Four habitat characteristics were noted at each site: 1). whether the pond was open or shaded by trees; 2). whether the surface was shaded by slough grass or clear of vegetation; 3). whether or not there were willows, conifers or poplars around the margin; and 4). whether the water body was stagnant or was continually fed by seepage or continuous surface run-off. In 1978 water analysis was also made at each site containing larvae. The pH, conductivity, temperature, and dissolved oxygen content at the time of sampling were recorded with a view to further characterization of habitats of individual *Aedes* species.

RESULTS

Thirty-four species of mosquitoes in four genera were collected in this survey. Twenty-seven of these species belong to *Aedes*, most larvae of which inhabit temporary bodies of water formed by melting snow or rainfall. Although not important vectors of disease in Alberta, some species develop huge populations with a high nuisance rating.

The species of *Aedes* show four distribution patterns (Fig. 3). Group 1 mosquitoes are largely restricted to the mountains and foothills; Group 2 mosquitoes occur in all 4 zones; Group 3 mosquitoes occur in 3 of the zones, but are missing from the prairie; and Group 4 mosquitoes are largely restricted to the parkland and prairie. Some overlap at the foothills-parkland border is not uncommon in species in Groups 1 and 4. Because of rarity, the distribution of seven species could not be ascertained.

Group 1 - Mountain and Foothills species

Aedes (Ochlerotatus) canadensis (Theobald) ..... (15 collections)

This species is included in the mountains-foothills group although specimens were taken at two sites west of Calgary at the western edge of the parkland zone. Most larvae were found in spring, but were also collected in summer in the mountains in 1977. Most were found in unshaded locations in forested areas, and in non-stagnant pools. The species was found on only three occasions by itself; at other times it was associated with one or more of nine species of *Aedes*.

Aedes (Ochlerotatus) communis (de Geer) ..... (36 collections)

Classification of this species is discussed by Ellis and Brust (1973). It was one of the commonest species in the mountains and foothills, where larvae were found only in spring in snow-melt pools. Larvae were in forested areas, but in relatively open pools. The water in most pools was clear and cool and laboratory rearing was much more successful when the water was kept clear and well aerated. The species was found on 10 occasions by itself; at other times it

was associated with one or more of 20 other species.

Aedes (Ochlerotatus) hexodontus Dyar ..... (34 collections)

Larvae of this species are also common inhabitants of open pools in the mountains, often found with larvae of *Ae. communis* and *Ae. punctor* . Predominantly a spring species, larvae were found at one location in the mountains in the summer of 1977. According to Carpenter and LaCasse (1955), some hatching may be delayed until long after the pool has been filled by snow-melt. It was rarely found by itself (four collections), occurring at one time or another with 19 other species.

Aedes (Ochlerotatus) pionips Dyar ..... (11 collec

Not a common species, found predominantly in spring in open locations in forested areas of the foothills, although larvae were collected during the summer on one occasion in the mountains in 1977. It was found once by itself, on other occasions being associated with one or more of 17 other species. Larvae were difficult to rear, even in clear, well aerated water.

Aedes (Ochlerotatus) pullatus (Coquillett) ..... (47 collections)

One of the most common mountain species, larvae were in open pools in both spring and summer. In 1977 it was found alone in a pool near the Columbia Icefields on 10th May (water temperature 14°C) and again on 5th July (water temperature 20°C). On both occasions 4th stage larvae and pupae were present, and the indication is therefore that eggs hatched on two occasions in 1977. The species was not present in this pool in the spring of 1978; *Ae. communis* was there instead. *Aedes pullatus* was found on 10 occasions by itself, and on other occasions with 20 other species.

Aedes (Ochlerotatus) punctor (Kirby) ..... (33 collections)

Another common mountain - foothills species, collected mainly in spring but also taken in a few summer samples in 1977 and 1978. Larvae apparently prefer grass-covered, willow-fringed, open pools. Found on three occasions by itself, it occurred at other times with 23 other species of *Aedes*.

Aedes (Ochlerotatus) schizopinax Dyar) ..... (11 collections)

Like *Aedes canadensis* this species has been taken from the western edge of the parkland, but is otherwise restricted to the mountains and foothills. It is rather local, being found at only one location in 1978, but it did occur in fairly high numbers in certain locations in the southern part of the study area during the summer of 1977, when its larvae were among the most common in the Coleman area. Almost all samples were in open, grass-covered pools. Nielsen (1961) reports that larvae prefer small to moderately sized pools containing considerable vegetation and organic matter, often covered with scum. He also reports that adult females are not known to take blood meals. *Aedes schizopinax* was found only once by itself; at other times it occurred with one or more of 16 other species. During spring, larvae appeared later than those of the other species, but developed quickly both in the field and laboratory.

Group 2 - Ubiquitous Species

Aedes (Ochlerotatus) cataphylla Dyar ..... (90 collections)

A common species in all zones, apparently having a wide tolerance of habitat conditions. It is a spring species, and was the most frequently encountered species in the spring of 1976. Eggs apparently hatch on the first flooding, whether warm or cold, and this could account for the two records of larvae in the summer sampling in 1977. Larvae developed quickly and Carpenter and LaCasse (1955) report that it is one of the first *Aedes* species to appear on the wing. Fourth larval and pupal stages suffered heavy mortality when reared in the laboratory. *Aedes cataphylla* larvae were found alone on 14 occasions, and with 22 other species at other times, especially *Ae. campestris, Ae. fitchii,* and *Ae. mercurator* .

Aedes (Ochlerotatus) euedes Howard, Dyar and Knab ..... (45 collections)

This species was fairly common in the 1976 survey, but was not recorded as frequently in 1977 or 1978. It is primarily a snow-melt pool species, but small numbers of larvae have been found in rain-water pools during the summer in the mountains. Larvae were found in many types of pools in all four ecological zones. It occurred only six times alone, at other times being associated with 17 other *Aedes* species. This was the most difficult of the commoner species to rear in the laboratory, partly because the larvae were very aggressive and apparently unable to withstand even slight crowding. Rate of development was about average, but overall development time was long because individuals grew to a larger size than most other species. In the spring of 1975, this species required six to seven weeks to complete development from egg to adult (Enfield, unpubl. obs.). Enfield (1977) and Wood (1977) discuss nomenclatural problems surrounding this species.

Setae vary between western and eastern Canadian populations. In Alberta abdominal seta 7-II is multiple (more than four hairs), whereas eastern specimens have seta 7-II with three or fewer hairs (Wood, pers. comm.).

Aedes (Ochlerotatus) fitchii (Felt and Young) ..... (65 collections)

This common species in 1976 was less so in 1977 and 1978, but was widely distributed in open habitats. As might be expected of a widely distributed species, it was rarely found alone (three collections), but was found at one time or another with 22 other species, frequently with *Ae. cataphylla.* It was found primarily in the spring, but also in the summer on two occasions in 1977. The larvae were among the slowest developers, many being in the second stage when other species in the same water body were in the fourth. Larvae were easy to rear.

Aedes (Ochlerotatus) implicatus Vockeroth ..... (44 collections)

Another early species which was, however, found in a few locations in the summer of 1977. It has a wide tolerance of habitat conditions and is clearly not restricted to montane, forested regions as stated by Carpenter and LaCasse (1955). Found on seven occasions alone, it occurred at other times with 23 other species. The larvae were easy to rear in the laboratory.

Aedes (Ochlerotatus) increpitus Dyar ..... (17 collections)

Another species which was much commoner in 1976 than in the later years. Larvae prefer open ponds in the foothills in the southern half of the region, and were found in enormous numbers at Cayley in 1976. Although rare in mountains and prairie, this species is included in the ubiquitous category rather than creating a separate category for it. All records were from spring sampling except for a sole mountain record which was taken in the summer of 1977. It was rarely (two collections) found in the absence of other species. The larvae, like those of *Ae. mercurator* to which they are rather similar, are distinctly yellowish in life, unlike those of most black-legged species.

Aedes (Aedimorphus) vexans (Meigen) ..... (40 collections)

Aedes vexans is normally one of the commonest species in this area. However in the dry years of this survey it was found on only two occasions in 1976 and 2 occasions in 1978. Normally thought of as a typical summer species, all of the 1976 and 1978 records were from spring sampling, and all of the records from the northern part of the region in 1977 were also taken in the spring. *Aedes vexans* normally requires water temperatures above 8°C and a period of prior conditioning for successful hatching (Horsfall, 1956). However in 1977 eggs were hatching at much lower water temperatures. Our records show that larvae are found usually in open, grass-covered ponds throughout the region. The larvae were found associated with 21 other species, and on only seven occasions were they the only *Aedes* larvae taken at a site. The larvae are quite easy to rear in the laboratory.

Group 3 - Non-prairie Species

Aedes (Ochlerotatus) excrucians (Walker) ..... (40 collections)

This species was widely distributed through the mountains, foothills and parkland region. Larvae were primarily in open, grass-covered ponds in forested areas at higher elevations. Individuals develop slowly, like those of *Ae. fitchii,* to which they are very similar in many respects. On only five occasions was *Ae. excrucians* the only species taken at a site; on other occasions it was associated with one or more of 20 other species. It was found only during spring, except for the single 1977 record.

Aedes (Ochlerotatus) mercurator Dyar ..... (40 collections)

Except for two mountain samples in 1978 this species was taken during spring. Open, snow-melt pools in non-forested areas are preferred. Like *Ae. euedes, Ae. mercurator* larvae survive well in very cold water (Enfield and Pritchard, 1977). The confusion with *Ae. stimulans* in Alberta is discussed by Enfield (1977). Many larvae were associated with those of *Ae. cataphylla.*

Group 4 - Parkland and Prairie Species

Aedes (Ochlerotatus) campestris Dyar and Knab ..... (76 collections)

One of the commonest species in the study area, *Ae. campestris* was found in all 4 zones but was characteristic of open country and much commoner in the parkland and prairie than in the mountains and foothills. Most larvae were in open pools, without marginal vegetation. Rempel (1950) reports larvae from pools rich in organic matter with a pH on the alkaline side, but since all of the locations from which larvae were taken in this study were alkaline the latter criterion is not particularly helpful. Larvae were found during both spring and summer sampling. The species was found alone on six occasions, but at other times with 17 other species, frequently including *Ae. dorsalis* and *Ae. cataphylla* . The larvae were notably paler than those of other species and were very easy to rear in the laboratory, being able to withstand considerable crowding and fouling of the water. Development was rapid, except under crowded conditions when the rate slowed, although larvae survived well for long periods.

Aedes (Ochlerotatus) dorsalis (Meigen) ..... (66 collections)

This species was one of the commonest in the survey and was found in all four zones, although it was taken at only one location in the mountains and at only a few in the foothills. Most larvae were in open pools without marginal vegetation. It is normally thought of as a summer species and was indeed uncommon in the spring of 1976 and was commoner during summer of 1977 than in the spring of that year. However, in 1978 it was much commoner during spring than in the summer. This was the only *Aedes* species present at 10 sampling sites, and was found with one or more of 16 species on other occasions. Associated species were *Ae. vexans, Ae. cataphylla,* and *Ae. spencerii.*

Aedes (Ochlerotatus) flavescens (Muller) ..... (73 collections)

This was one of the most common species encountered in the survey. It was widely distributed over the parkland and prairie regions and was also taken in the foothills zone, although rarely. Like so many other spring species, larvae were taken during summer of 1977, presumably reflecting lack of snow-melt pools in that year. Larvae were generally at an earlier stage than those of other species in the same water body and this slow rate of development could be a disadvantage in years when pools dry up quickly. Because of its geographical distribution most larvae were in open habitats without marginal vegetation. Only twice found in the absence of other species, *Ae. flavescens* often occurred with *Ae. campestris.* According to Carpenter and LaCasse (1955), adult females may survive until late in the season, and in July 1977 females were biting during the day in the southern part of the region.

Aedes (Ochlerotatus) melanimon Dyar ..... (13 collections)

This species was only found in the southern part of the parkland and prairie zones during the summer of 1977. Most larvae were in open, grass-covered ponds, without marginal vegetation and frequently fed by water from more permanent sources. First recorded in Canada from Brooks, Alberta by Burgess (1957), this species was taken in only 13 sites in this survey. It occurred with 9 other species, including *Ae. vexans* on 12 occasions and *Ae. dorsalis* on 11 occasions.

Aedes (Ochlerotatus) spencerii (Theobald) ..... (71 collections)

Like *Aedes flavescens,* this species occurs occasionally in the foothills zone, but it is so widespread over the parkland and prairie that it is best considered in this latter group. It was one of the commoner species in this survey, even though it was only taken three times in 1977.

In that year, it presumably suffered, as did many other spring species, from the lack of suitable snow-melt pools in the parkland and prairie zones. *Aedes spencerii* was found alone more than any other species (27 times), and had a relatively low number of associated species (13) for such a common mosquito. In addition, there were usually few larvae of any species in the pools in which it was found.

Species of Uncertain Distribution

Aedes (Aedes) cinereus Meigen ..... (11 collections)

The few records for this species are from the mountains, foothills and western edge of the parkland, where larvae were found in pools fringed by poplars and willows. During this survey, it was found only during spring, but during a population study in 1974 eggs hatched both in the spring and later in the year along with *Ae. vexans* (Enfield and Pritchard, 1977).

Aedes (Ochlerotatus) diantaeus Howard, Dyar and Knab ..... (4 collections)

This species is, according to Rempel (1950), rare and local and found only in forested regions of Canada. Most larvae were collected from open, grass-covered pools with marginal evergreens and willow, in water that was not completely stagnant. Carpenter and LaCasse (1955) report the larvae from pools of melting snow, and both collections in 1978 were made during spring. In 1977, however, larvae were taken in rainwater pools during the summer. These are the first records for southern Alberta outside of the National Parks (recently reported from Banff National Park; Wood, pers. comm.). *Aedes diantaeus* was reported by Happold (1965) from Flatbush, 150 km north of Edmonton.

Aedes (Ochlerotatus) impiger (Walker)
..... (4 collections)

Larvae were found only three times: twice in the mountains in 1977 and once in the foothills in 1978. Open, grass-covered, non-stagnant pools with marginal evergreens were the typical habitat. A single adult female was taken in the parkland south of Lethbridge.

Aedes (Ochlerotatus) intrudens Dyar ..... (3 collections)

A rare species whose larvae are found only in shaded, snow-melt pools with marginal willows and poplars in the foothills and mountains.

Aedes (Ochlerotatus) nigromaculis (Ludlow) ..... (1 collection)

The rarest species of *Aedes* encountered in the survey, *Ae. nigromaculis* was found only once in an open, grass-covered pool formed from irrigation seepage into a grassy ditch, north-west of Lethbridge during the summer collecting period in 1977. According to Rempel (1950) it is a species of the open prairies and has been recorded previously from Lethbridge and Medicine Hat. Perhaps the record for Beaverlodge (55° 13'N, 119° 26'W) (Strickland, 1938) is in error.

Aedes (Ochlerotatus) sticticus (Meigen) ..... (6 collections)

Enfield (1977), having seen larvae of both *Ae. implicatus* and *Ae. mercurator* misidentified as *Ae. sticticus* , suggested that the record by Pucat (1965) needed to be verified. Five samples taken in 1977 and one in 1978, in late May or June, certified its presence, although it is apparently not common. Larvae were taken from open or shaded grass-covered pools, generally with marginal willows. The species was not collected from the mountain zone.

Aedes (Ochlerotatus) trichurus (Dyar) ..... (3 collections)

This species was not common, with larvae being found only in a few willow-fringed pools in the foothills and mountains. The larvae developed quickly, but were not easy to rear. They are large, and like those of species which have banded-legged adults, have a distinctly yellowish appearance in life.

Genera other than *Aedes*

The following species in the genera *Anopheles*, *Culiseta* and *Culex* overwinter as adults. In the spring they are the first mosquitoes to be seen on the wing, especially the genus *Culiseta*, whose adults are quite large. Adults appear as early as April if the weather is warm, but the larvae tend to appear later in the season (late springearly summer) after the appearance of the larvae of aedine species. The females lay their eggs on the water surface and there is no conditioning of the eggs, which hatch within a few days.

Anopheles (Anopheles) earlei Vargas ..... (2 collections)

There are no previous records of this species occurring in southern Alberta. Specimens were taken from a site near Twin Butte in 1977 and another site in Waterton National Park on the Red Rock Canyon Road in 1978. The abundance of this species is usually quite low and local and no serious outbreaks have been recorded.

Culex (Culex) tarsalis Coquillett ..... (10 collections)

This species is represented across the entire southern half of the province, and is especially prevalent in the irrigated areas. Western equine encephalitis is associated with this species (Shemanchuk 1969), and if weather and irrigation conditions are correct, it could prove to be a problem. In the southern part of the study area it was often found in shallow pools in pasture fields flooded by irrigation water as well as roadside ditches.

Culex (Neoculex) territans Walker ..... (4 collections)

This is the first record of *Culex territans* south of Edmonton. We found it locally only in the foothills. Most larvae were associated with bodies of water that contained a lot of vegetation.

Culiseta (Culiseta) alaskaensis (Ludlow) ..... (17 collections)

Strickland (1938) reports this species from Banff National Park, the Nordegg area, and the Calgary/Ft. Macleod area. It would seem to prefer higher elevations, being found in our survey only in the mountains and foothills except for two records west of Calgary in the parkland. This species was on the wing in early May in Jasper National Park in 1978, and was a persistent biter.

Culiseta (Culiseta) incidens (Thomson) ..... (2 collections)

This species was very rare in the study area having been found only once at Rocky Mountain House in 1977 and once northeast of Banff in 1978.

Culiseta (Culiseta) inornata (Williston) ..... (47 collections)

This is the most widespread *Culiseta* in southern Alberta and one of the most troublesome species in the Lethbridge area during the summer, when, regardless of weather conditions, irrigation produces ideal breeding grounds. *Culiseta inornata* is a troublesome biter of both man and livestock as well as wild ungulates, and has been associated with western equine encephalitis (Shemanchuk 1969).

Culiseta (Culicella) morsitans (Theobald) ..... (1 collection)

Only one specimen of this species was taken during the study period, being taken south of the Jasper townsite during the spring of 1977. According to Rempel (1950) it is very rare in Western Canada, but has been previously reported from Alberta (Dyar, 1928; Wada, unpubl.).

DISCUSSION

During the three years of this study a number of changes have been made to published lists (e.g. Pucat, 1965) of mosquitoes in southern Alberta. Enfield (1977) revealed the presence of one species not previously recorded from Canada namely *Aedes schizopinax* . This species in fact, has a wide distribution in the southern part of the mountains and foothills. It had previously been found in Calgary by Robins (1972, unpubl.) and Scholefield (1973, unpubl.), but not officially recorded.

Aedes euedes has a very wide distribution across the entire survey area (Fig. 3). Previously identified as *Ae. barri* or *Ae. riparius,* its naming as *Ae. euedes* has now been properly established (Wood, 1977). *Aedes stimulans,* which, according to records, had a wide distribution in Alberta, apparently does not occur in the province. All specimens identified as such, appear to be *Aedes mercurator* (Enfield, 1977; Wood, 1977), which is widely distributed in the mountains, foothills, and parkland of the study area (Fig. 3).

Aedes increpitus is now recorded from southern Alberta, being first found in the Calgary area by Scholefield (1973, unpubl.). It was not found north of Calgary, however. Enfield (1977) indicated that the presence of this species in northern Alberta is suspect due to the fact that all the records he had seen from that area were actually *Ae. mercurator.*

Another new record for southern Alberta is *Aedes implicatus* , being first recorded by Enfield (1977). It ranges across the entire southern half of Alberta, although it is local in the prairie.

Northern records for *Aedes hexodontus* have been published by Pucat (1965), Graham (1969), and Tawfik and Gooding (1970). It too was first recorded in southern Alberta during the first year of this present study (Enfield, 1977). Its distribution is restricted to the mountains and foothills where it is quite common.

The ranges of six other species (*Ae. canadensis, Ae. pionips, Ae. punctor, Ae. communis, Ae. trichurus* and *Ae. pullatus)* have been somewhat extended. Previous reports in the literature listed Banff as the only site in southern Alberta (Strickland, 1938; Rempel, 1950). All are more or less restricted to the mountains and foothills, areas which have not been

previously extensively collected.

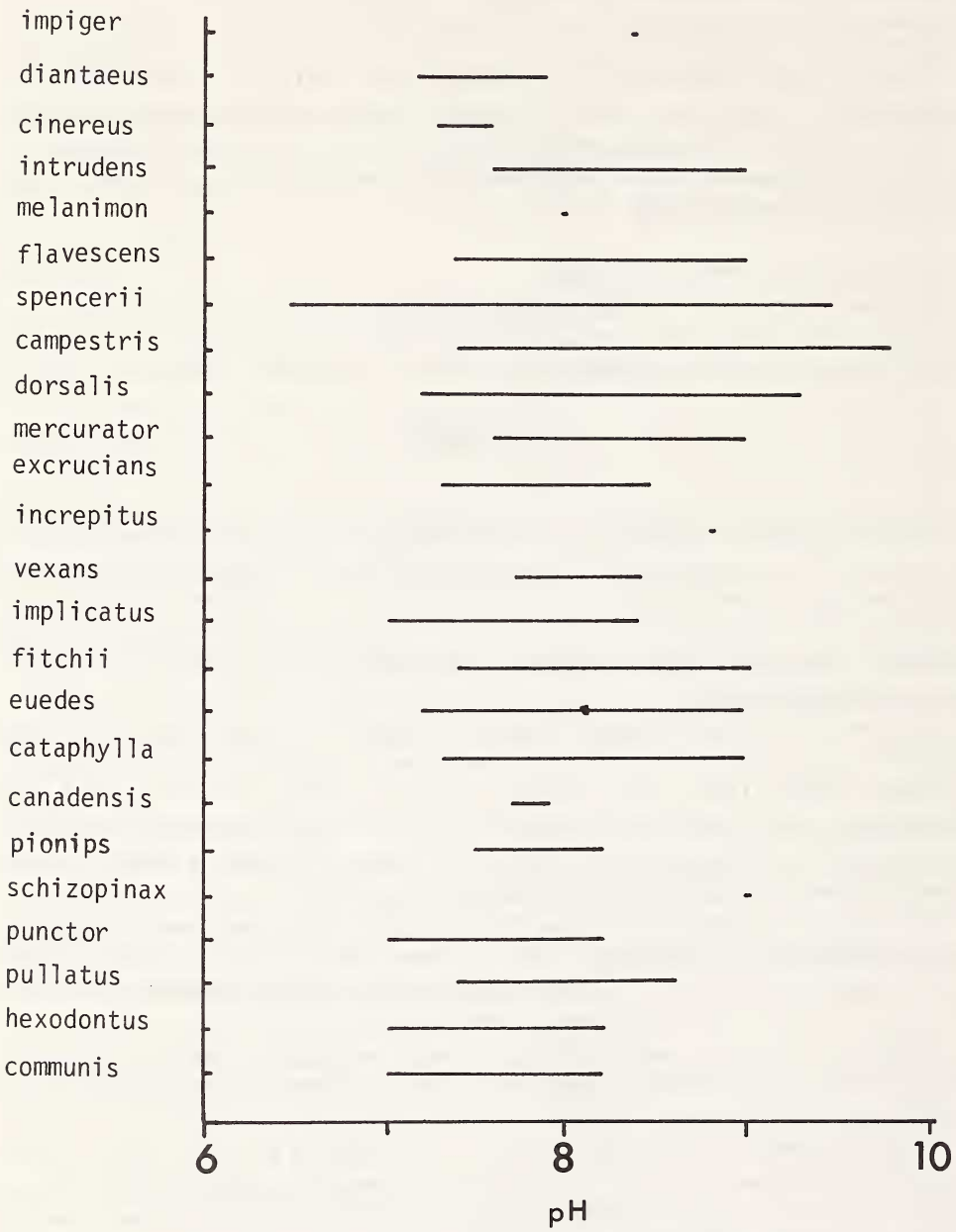

Fig. 4. The range of pH of the sites from which larvae of 24 species of *Aedes* were collected.

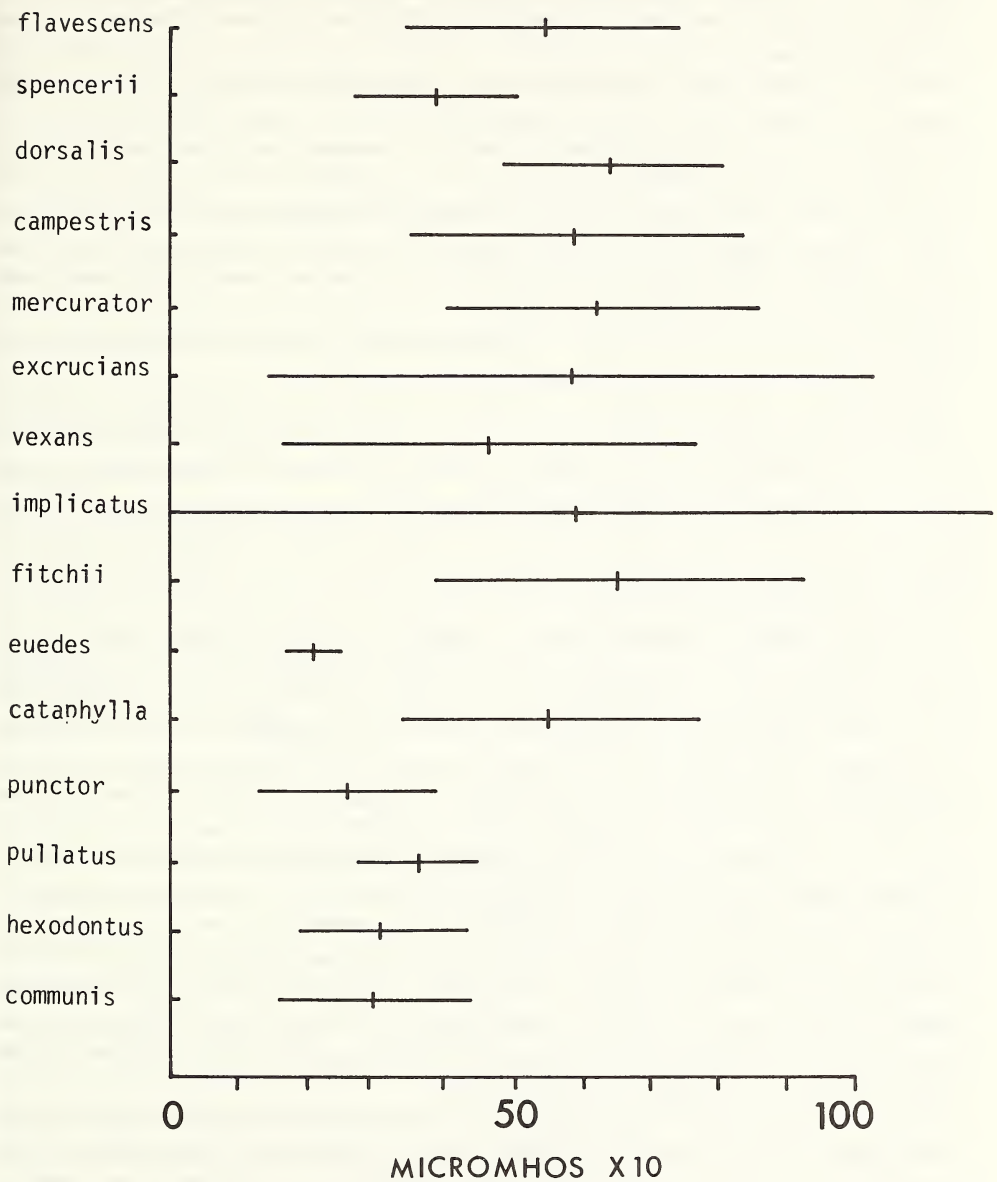

Fig. 5. The specific conductance (mean ± 95% confidence limits) of the sites from which larvae of 15 species of *Aedes* were collected.

Factors affecting mosquito distribution in southern Alberta are largely unknown. Most species encountered in this study have wide distributions, although 15 species were collected only from the mountain - foothills region and six were more or less restricted to the parkland - prairie. On a finer scale, habitat distinctions between species are impossible to make on the basis of information collected in this survey. Of the 20 species which were collected on at least 10 occasions, all but two were associated with 13-20 other species at one time or another, and the other two species had nine associated species. Clearly, with such overlap there is no such thing as a unique habitat for each species. This problem was further exposed when characteristics of the individual sites were considered. There were few obvious departures from the typical set of habitat conditions for the area, nor were there any obvious differences in pH (Fig. 4) or specific conductance (Fig. 5) of the water bodies inhabited by the different species. Water in the mountains and foothills has lower conductivity than water in the plains, and species restricted to these areas are therefore found in water with lower conductance values. This does not, of course, imply that conductance of the water is the reason for restriction of these species to those zones. Similarly, water bodies in the mountains and foothills are more likely to be shaded than are those in the parkland and prairies.

Maire and co-workers (e.g. Maire and Aubin, 1976; Maire *et al.,* 1978; Mailhot and Maire, 1978) have related the distribution of mosquito larvae to vegetation types in Québec. However, the analysis is rarely clear-cut, even with only one half of the number of *Aedes* species that are present in southern Alberta. For example, Maire (1977) proposes four associations based on abundance of four species of *Aedes* and two of *Culiseta.* However, except for *Ae. decticus,* which is found only in open sites, all species occur in all habitats, and three species are abundant in more than one habitat type.

A further difficulty in judging habitats as suitable or not for particular species is that relative species abundance can change quite markedly from year to year. There was a marked decline in number of sites at which the 18 most common species were taken from 1976 (355 sites) to 1977 (226 sites), even though there was no summer sample nor were the mountains well sampled in 1976. There was only slight recovery in 1978 (273 sites). Particular species worth noting are *Ae. campestris, Ae. cataphylla, Ae. euedes , Ae. fitchii , Ae. flavescens,* and *Ae. mercurator* which were all common in 1976, but much reduced in numbers in later years. *Aedes euedes* and *Aedes mercurator* are especially noticeable since together they were so abundant at a pond just northwest of Calgary in 1975 that they provided excellent material for a population study (Enfield and Pritchard, 1977). Also noticeable are *Ae. vexans* , normally thought of as the commonest species in this area, but which only achieved any level of relative abundance in 1977, and *Ae. spencerii* , which was uncommon in 1977, but the commonest species in 1978. Records were not kept of individual pools from year to year, except for a pool near the Columbia Ice Fields which had two hatches of *Ae. pullatus* in 1977, but none in 1978. In the latter year, *Ae. communis* was present instead.

Overall changes in abundance of mosquitoes are clearly related to number of pools formed by snow-melt or rainfall. Availability of snow-melt pools depends upon amount of snow-fall, pattern of Chinook winds during winter, and speed at which snow disappears during spring. During this survey, there appeared to be fewer snow-melt pools in 1977, especially in the parkland and prairie, than in other years. Rain-filled pools depend on the pattern of precipitation during spring and summer, and on the level of the water table. There were fewer such water bodies in 1978 than in 1977. Overall, the three years of this study coincided with a period of relative drought which was inimical to development of mosquito populations. Our

experience with *Aedes vexans* exemplifies this trend. In 1972 (Robins, unpubl.) and 1973 (Scholefield, unpubl.), *Ae. vexans* was abundant in the Calgary area. In August of 1974 at an experimental site outside Calgary, larvae of *Ae. vexans* were abundant, but the pond dried up before larvae had completed development (Enfield and Pritchard, 1977). In 1975, the pond flooded at snow-melt, was dry by early June and remained so for the rest of the year and no *Ae. vexans* eggs hatched. At our experimental sites in N.W. Calgary it was necessary to artificially flood pond beds in 1976 and 1977 in order to have populations with which to work. In 1978 these ponds flooded naturally in April, but dried up permanently for the year at the beginning of July. No *Ae. vexans* larvae appeared. These trends applied generally over the whole study area.

Related to the pattern of precipitation is the distinction between "spring" and "summer" species, a concept which is by no means as tidy as many hold it to be. Spring species are those whose eggs generally hatch on the first flooding of the year, this normally being the result of snow-melt, and an egg diapause restricts the number of generations per year to one. Exceptions to this latter statement may be *Ae. pullatus* and *Ae. cinereus* (see above), and perhaps other species (see Magnarelli, 1977). Montane and foothills species generally belong to this group, as might be expected since there will be an abundance of snow-melt pools in these regions. So-called "spring species" apparently hatch in the first flooding whether warm or cold and this accounts for their appearance in summer samples, especially in 1977 when there was a dearth of snow-melt pools. However temperature requirements for hatching in these species appear not to have been well studied.

Hatching of eggs of summer species such as *Ae. vexans* and *Ae. dorsalis* is complicated (Horsfall, 1956). The basic pattern is that eggs that have completed embryogeny hatch only after a period of drying, flooding with water above 8°C and a lowering of oxygen concentration. However, there is variability between populations in response to these factors and even given these conditions many eggs do not hatch. This erratic hatching has been viewed by some authors as an inherent safeguard against unpredictable water conditions, but Gillett *et al.*, (1977) have suggested that in *Ae. aegypti* this erratic hatching is due to the grazing of oxygen-consuming bacteria from egg surfaces by the first larvae that hatch. Egg diapause in *Ae. vexans* is also complicated (Taylor, pers. comm.).

Again, our experience with *Ae. vexans* is illustrative of the complexity of the problem. In our population studies in 1974 (Enfield and Pritchard, 1977), eggs of *Ae. vexans* behaved according to the above formula; i.e. no eggs hatched when flooded with water at 6°C and four subsequent floodings at 20°C were required in order to hatch all the eggs. Few, if any eggs, were laid in our experimental field sites in 1974 or 1975 and so there were few eggs available in the ground in 1976 or 1977. When they were hatched artificially by flooding with water above the threshold for hatching in the laboratory in these years, the hatch was complete with one flooding, perhaps because of the low density and supporting the hypothesis of Gillett *et al.*, (1977). However, more interestingly, in the survey, *Ae. vexans* larvae were generally taken in spring sampling rather than summer sampling and the evidence suggests that eggs were hatching in much colder water than the accepted threshold. Eggs of *Ae. vexans* collected from soil cores in 1977 were in fact hatched in the laboratory at temperatures below 8°C. The same remarks apply to *Ae. dorsalis* in 1978.

In view of the confused literature on this subject (e.g. Horsfall *et al.*, 1973) and in light of the above observations, a renewed study of the hatching requirements of *Aedes* eggs would seem to be in order. Such a study might go a long way towards explaining the distribution and

abundance of different species from year to year.

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